U.S. DEPARTMENT OF AGRICULTURE FOREST PEST LEAFLET 78
Forest Service August 1963

Armillaria Root Rot

By Charles D. Leaphart[1]

Armillaria root rot is found on many species of trees, shrubs, and vines throughout the world. It is caused by the fungus *Armillaria mellea* Vahl ex Fr. that invades the roots of woody species not only in forests, but in orchards, along roadsides, and even in gardens. *A. mellea* also causes a decay, seldom extending more than a few feet above ground, in the heartwood of broadleaf trees such as oak (fig. 1) and sugar maple, and in conifers such as western hemlock. Much of the older information about its effect on forest trees comes from studies and experience in Europe.

Armillaria root rot is described under a variety of common names. "Shoestring root rot" is one widely used and refers to a special means of infection and spread (rhizomorphs). Others are "crown rot" from the decay it causes at the root collar; and "mushroom root rot," "rhizomorphic root rot," and "toadstool disease." The names are based on the infectious and reproductive structures of the fungus. Descriptive of a symptom found on some infected conifers, the disease is also sometimes called "resin glut" or "resin flow."

The causal fungus is sometimes called the "oak fungus" since oak is one of its preferred hosts. "Honey mushroom" and "honey agaric" are other common names for the fungus derived from the color of the fruiting bodies.

Disease Characteristics

Some of the more generalized symptoms of Armillaria root rot resemble those of other root diseases. These are abrupt or gradual reduction in growth, yellow foliage, branch death particularly in the upper crown, and resin or gum exudation on roots or near the root collar. These symptoms may appear singly or in combinations in an infected tree.

Decayed areas may be present at the root collar or on the roots. Veined, white mycelial fans, formed between the bark and wood where the cambium has been killed, are typical signs (fig. 2). Rhizomorphs or "shoestrings" also form on the roots, under the bark, or in severely decayed wood and may radiate into soil surrounding the roots.

These characteristics help in diagnosis, but the presence of Armillaria root rot can be confirmed if mushrooms of the fungus are found attached to diseased trees. The root rot can be positively identified from pure cultures of the fungus that have been isolated from woody

[1] Forest pathologist, Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Ogden, Utah.

F–502794

Figure 1.—Heartwood decay in black oak caused by *Armillaria mellea*. Remnants of fruiting bodies are indicated by the arrows. The decay column, delineated by white lines, extended but a few feet beyond the top of the vertical section.

material suspected of having been invaded. *Armillaria mellea* is easily identified in pure culture when sinkers or "branched rhizomorphs" develop in the culture media.

The mushrooms grow on the lower trunk of dead or dying trees, on stumps, or on the ground near infected roots. They are short-lived, annual-fruiting bodies that may occur singly but more commonly in groups of several to 100 or more (fig. 3, *A*). Each such fruiting body has a yellow or brown stalk 3 inches or more long and a broad cap 2 to 5 inches across (fig. 3, *B*). The top of the cap is honey yellow and may be dotted with dark brown scales. The under side is covered by numerous loosely spaced, white or pale yellow gills radiating from the stem. A ring is sometimes found around the stalk just below the gills.

Cankers are formed on both conifers and hardwoods wherever *Armillaria mellea* successfully invades the cambium. Resin is exuded from the infected area on conifers, especially pines and other resinous species. Heavy flows may occur at the base of trees in which the fungus has progressed upward past the root collar. Compacted soil masses infiltrated with resin may be found around root infections. In nonresinous conifers, cankers are usually covered by loose bark. In hardwoods, cankers de-

F–501499

Figure 2.—Bark has been removed from the stump of a sugar maple to expose mycelial fans of *Armillaria mellea*. Basal scars in the same shape as mycelial fans are often encountered on living trees that have successfully, momentarily at least, checked further encroachment by the fungus.

velop on the roots or above the ground line and coincide with the white mycelial fans beneath (fig. 2). Gum or other exudates are usually associated with the cankers. Healing cankered areas that are sometimes mistaken for fire scars are found on both conifers and hardwoods after progress of the organism has been halted.

Spread

Like most forest fungi, *Armillaria mellea* is spread by means of spores, produced in this species on the gills of its mushrooms (fig. 3, *B*). Infestation from windborne spores occurs in dead stumps, trees, or other dead woody material. Infection of living trees from spores has not, however, been demonstrated.

The fungus also spreads by another means—rhizomorphs (fig. 4). A rhizomorph consists of a compact outer layer of dark brown to black mycelium and a core of white or hyaline mycelium. Rhizomorphs are usually found between the dead wood and the bark of roots. They elongate from their tips and radiate through the soil from dead roots or stumps to infect living trees. They may penetrate either wounded or unwounded surfaces. Infection is believed to be more likely on weaker, less vigorous roots of any tree, independent of its overall health.

Spread from infected material to living trees may also occur through root contact. The fungus mycelium may directly invade living roots appressed to diseased roots without

F–502804 F–503129

Figure 3.—Fruiting bodies of *Armillaria mellea*: *A*, On the lower trunk of a yellow birch; *B*, closeup view showing the gills on the under surface that bear the spores.

F—503130

Figure 4.—Rhizomorphs of *Armillaria mellea*. "Shoestrings" on the surface of the dead wood beneath the bark have been exposed.

forming rhizomorphs. But the vigor of a root probably affects its susceptibility to this type of infection. Root contact may be more important for infection and spread than spores or rhizomorphs because contact between roots of many susceptible species is common in forest stands. However, both root contact and rhizomorphs account for spread in centers of Armillaria damage (fig. 5).

Damage

As a primary killer of trees in natural forest stands, the importance of *Armillaria mellea* has probably been overemphasized. The fungus usually lives as a saprophyte and obtains its food from dead stumps and roots and the heartwood of living trees. But it may also live in the lower stem or roots as a parasite on living tissues. Here it often attacks hosts already weakened by unfavorable environment, injuries, insects, or by other diseases (fig. 5) and is, therefore, considered a "pathogen of opportunity."

How much this organism contributes to tree death or reducing tree growth is difficult to know, since trees, whether weakened initially in other ways, may regain their normal growth rate following Armillaria invasion. Damage from Armillaria root rot frequently peaks a year or more after several consecutive dry summers, but severity of damage varies by locality, host, site, and year. Hence, the annual economic loss from reduced

F—502803

Figure 5.—An Armillaria center in a mixed-conifer type on the Deschutes National Forest, Oreg. The causes of occurrence of centers such as this are not always understood. But *Armillaria mellea* is frequently found associated with dead and dying trees already damaged by other causes. Its share in causing the death of such trees is unknown.

growth and death of trees caused by *Armillaria mellea* (whether direct or indirect) and from decay it causes in heartwood of living trees is probably underestimated.

This root rot not only decays heartwood, but may also decay sapwood after killing the cambial tissue. When wood first begins to decay, it usually appears faintly water-soaked; a light brownish color is more apparent later. Wood advanced in decay is light yellow or white, soft and spongy in hardwoods and often stringy in conifers, and marked by numerous black lines. Infectious rhizomorphs may be found occasionally in extremely decayed wood.

Armillaria mellea also has a beneficial role in nature as a wood-destroying fungus. It contributes to the carbon cycle by decaying stumps and roots left in the woods after logging or after trees die. Furthermore, without decay by the many scavenger fungi, including Armillaria, dead woody material would accumulate, leaving young trees no place to grow. But in its beneficial role, the fungus may stay alive in roots and stumps for long periods. Thus, a source for its spread to other trees and other areas is always maintained.

Control

Just as for many similar diseases, direct control is rarely possible under present forest conditions. Preventive measures that maintain conditions favorable for rapid and vigorous tree growth will usually keep damage by this disease to a minimum and are generally more practicable. Drastic openings should not be made in carrying out partial harvest cuttings or thinnings. Plantations of trees unsuited to an area may be severely damaged because the site does not provide for their vigorous growth. Such plantings should be discouraged. Girdling trees a year or more before they are to be cut has been recommended to prevent subsequent invasion of their roots and stumps and, thereby, creation of Armillaria centers. Girdling might be most appropriately used before removing trees from recreational developments, seed orchards, and other areas of high value. Until more is learned about direct control procedures, these preventive measures offer the best opportunity for control in forest stands where Armillaria is a management problem.

Direct control may be more appropriate for valuable shade, ornamental, and orchard trees. Even here, it may be too late to save a tree after its diseased condition is discovered, but adjacent trees can be protected. Careful removal of its stump and roots will eliminate most sources of further infection. Roots of adjacent healthy trees should not be injured when diseased roots are removed and when lawn areas are graded and reseeded.

Chemicals have been used most effectively to treat contaminated soil that is to be planted to cultivated tree crops. Certain fumigants have been particularly effective; for example, carbon disulfied has been used for many years in California to control *Armillaria*

mellea in citrus orchards. Professional advice should be secured before chemicals are employed. Recommendations for control will vary over the wide range of soil conditions and hosts on which Armillaria occurs.

Caution: Fumigants are poisonous and should be used with due precaution and according to recommendations of the manufacturer. They should be stored in a safe place, properly labeled, and away from food.

References

FOREST PATHOLOGY. J. S. BOYCE. McGraw-Hill, New York, 550 pp. 1948.

ENVIRONMENT AND DISEASE. A DISCUSSION ON THE PARASITISM OF ARMILLARIA MELLEA (VAHL.) EX FR. W. R. DAY. Forestry (Gt. Britain) 3:94–103. 1929.

BIOLOGY OF ROOT-INFECTING FUNGI. S. D. GARRETT. Univ. Press, Cambridge, 293 pp. 1956.

STUDIES ON ARMILLARIA MELLEA (VAHL.) QUEL., INFECTION, PARASITISM, AND HOST RESISTANCE. H. E. THOMAS. Jour. Agr. Res. 48: 187–218. 1934.

U.S. GOVERNMENT PRINTING OFFICE: 1963 O—685-277